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by

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Abstract: This paper examines the effect of competition in airline hub-and-spoke networks. Because of the cost complementarities inherent to such networks, competition in a single route usually creates negative externalities, causing a reduction in traffic throughout the network. Furthermore, competition may also imply a reduction in total social surplus. The paper suggests that antitrust policy toward airlines operating hub-and-spoke networks should be reconsidered.

I. Introduction

Airline deregulation has drastically changed the way airlines operate. The point-to-point network has given way to the hub-and-spoke network, in which passengers change planes at a hub airport on the way to their destinations. While certain airlines were able to develop, even under regulation, relatively efficient networks of the hub-and-spoke type (e.g. Delta with a main hub in Atlanta, and Allegheny, with a major hub in Pittsburgh), most airlines developed their hub-and-spoke networks after deregulation. This restructuring process was carried out through mergers and internal restructuring.

Despite the dramatic conversion to hub-and-spoke networks, the effect of of competition in such networks has not been given much academic attention.[1] In this paper, we address this issue by exploring the welfare and distributional implications of competition and mergers in airline networks. The main point of the paper is that while competition in selected hub-and-spoke routes may provide benefits to passengers on those routes, it may reduce the welfare of the remaining passengers in the hub-and-spoke system. The analysis thus suggests that elimination of such competition through mergers can generate potentially large network-efficiency gains that may under reasonable conditions compensate for the anticompetitive effects of moving from duopoly to monopoly on those selected routes. These potentially large network-efficiency gains are, however, obtained throughout the network and cannot be obtained by means other than the merger.[2]

The efficiency gains in mergers of this type (and the consequent inefficiencies of competition) arise because of the substantial economies of scale associated with the operation of larger aircraft. These economies of

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scale were the reason for the rapid adoption by most airlines of hub-and-spoke networks following deregulation.[3] Such networks allow hub airlines to carry pass-through passengers on their spoke routes, allowing utilization of larger aircraft and realization of lower average costs per passenger. Competition on a spoke route,[4] while reducing prices for passengers traveling to or from the hub, results in a reduction in the optimal aircraft size for that particular spoke, and increases the marginal cost of a pass-through passenger. Thus, the overall network efficiency of the hub-and-spoke airline is reduced. Conversely, the elimination of competition on a given spoke allows the hub airline to utilize larger aircraft on that spoke, increasing its overall network efficiency.

The Department of Transportation, which until the end of 1988 has the power of approving airline mergers, has declined to block any of the proposed mergers.[5] The Antitrust Division of the Department of Justice, on the other hand, has recommended blocking several mergers based on their potential anticompetitive effects.[6] These effects were viewed as arising from the reduction of the number of competitors in numerous nonstop routes (the usual DOJ concept of "antitrust markets").[7,8] In their recommendations against these mergers, the DOJ has argued that potential efficiency gains should not be considered. First, the DOJ has claimed that these gains could have been achieved through means other than the merger.[9] Second, it has claimed that since such gains would be obtained in antitrust markets other than the one in which the competitive injury is expected, the gains should be ignored.[10] Our analysis suggests that these views are misguided.

This paper is related to a recent literature on the effects of horizontal mergers.[11] The paper differs from this literature in three major

respects. First, while this literature focuses on single-product firms, airlines are multiproduct firms. Airlines provide point-to-point service to and from their hubs, as well as pass-through service. There are important product complementarities among these two services, with an expansion in one type of service reducing the marginal cost of providing the other.

Second, we do not consider the expansion of fringe firms in response to a merger, as is done in Farrell and Shapiro (1988) and Perry and Porter (1985). In most airline merger cases, antitrust concerns arose because of the reduction in the number of actual competitors from two to one in the presence of alleged substantial entry barriers. Hence, in those cases, the role of fringe firms was minor compared to that in most other industrial mergers. In both Farrell and Shapiro (1988) and Perry and Porter (1985), the expansion by smaller firms is at the heart of the potential efficiency gains from the merger. In our case, the expansion is not by independent firms, but by the complementary products that the airlines provide.

Finally, we do not analyze, as do Farrell and Shapiro (1988), the important role of complementary specific capital. Specific capital implies that a merger is not just the elimination of a competitor. Rather, the combination of the firms' specific capital may provide particular economies or diseconomies of scale. In the airlines' case, however, a well functioning rental market for airplanes makes the airlines' productive assets substantially mobile. Most of the specific and sunk investments seem to be concentrated in the creation of networks,[12] and in their airport facilities (gates). The merger of two airlines serving a hub provides the combined entity with more gates at the hub. The combination of their gates, however, does not in general imply a strong production advantage.[13]

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II. Monopoly Hub-and-Spoke Service

In analyzing the effect of competition, we first develop the monopoly solution as a benchmark case. A monopoly airline is assumed to serve four cities: A, B, C and H. The airline faces travel demands between any two of these cities. Under constant returns to scale at the passenger level, the airline would provide nonstop connections between any two cities. In the presence of economies of scale, however, the monopolist must chose whether to offer nonstop flights in some or all city-pair markets or to operate a hub-and-spoke system. In this type of system, travellers change planes at a hub airport on the way to their eventual destinations. While passengers may be willing to pay a premium for direct over connecting service,[14] the introduction of nonstop service imposes a cost on the airline. In particular, the lighter traffic volume on a nonstop route precludes exploitation of economies of scale.

In what follows, we assume that the optimal traffic configuration is a hub-and-spoke system, with city H playing the role of the hub because of its central location (see Figure 1). Aircraft are flown on three routes: A to H, B to H and C to H. On a given leg, say A to H, aircraft carry both local (i.e. A to H) passengers, as well as pass-through (i.e. A to B and A to C) passengers (traffic also includes passengers returning from A to B, C, and H).

For convenience we assume that demand is symmetric across city-pairs. Thus, the inverse demand function for round-trip travel in any given city-pair market ij is given by $D(Q_{ij})$, with Q_{ij} representing the number of round-trip passengers in the market.[15] Thus, for example, Q_{AB} represents

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the number of passengers flying from A to B and back, <u>plus</u> those flying from B to A and back. Associated with the demand function, there are revenue and marginal revenue functions. In the AB case, for example, revenue is $R(Q_{AB})$ = $Q_{AB}D(Q_{AB})$ and marginal revenue is $R'(Q_{AB})$.

Given the symmetric location of cities A, B and C with respect to H, we assume that a common cost function (denoted $c(Q)$) applies to each of the legs AH, BH, and CH. This function gives the round-trip cost of carrying Q passengers on the leg. The cost function reflects increasing returns to scale, with $c(Q)$ satisfying $c'(Q)>0$, and $c''(Q)<0$. The assumption of increasing returns is intended to reflect the economies associated with the utilization of larger aircraft. While larger aircraft may have higher fixed costs, they have lower average cost per seat mile. Thus, if there was a continuum of aircraft types, the cost function would exhibit decreasing average and marginal costs.

We now solve the monopoly case. The monopolist problem is represented by (1):

$$\text{Max } \{R(Q_{AH}) + R(Q_{BH}) + R(Q_{CH}) + R(Q_{AB}) + R(Q_{AC}) + R(Q_{BC})$$
$$- c(Q_{AH}+Q_{AB}+Q_{AC}) - c(Q_{BH}+Q_{AB}+Q_{BC}) - c(Q_{CH}+Q_{AC}+Q_{BC})\}$$

$$\text{w.r.t. } \{Q_{AH},Q_{AB},Q_{AC},Q_{BH},Q_{BC},Q_{CH}\}$$

(1)

In (1), $Q_{AH}+Q_{AB}+Q_{AC}$ equals total round-trip traffic volume on the AH leg, with $Q_{BH}+Q_{AB}+Q_{BC}$ and $Q_{CH}+Q_{AC}+Q_{BC}$ representing total traffic on the BH and CH legs respectively. Assuming interior solutions, the first order conditions to the monopolist's problem are

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$$R'(Q_{AH}) = c'(Q_{AH}+Q_{AB}+Q_{AC}) \tag{2}$$

$$R'(Q_{BH}) = c'(Q_{BH}+Q_{AB}+Q_{BC}) \tag{3}$$

$$R'(Q_{CH}) = c'(Q_{CH}+Q_{AC}+Q_{BC}) \tag{4}$$

$$R'(Q_{AB}) = c'(Q_{AH}+Q_{AB}+Q_{AC}) + c'(Q_{BH}+Q_{AB}+Q_{BC}) \tag{5}$$

$$R'(Q_{AC}) = c'(Q_{AH}+Q_{AB}+Q_{AC}) + c'(Q_{CH}+Q_{AC}+Q_{BC}) \tag{6}$$

$$R'(Q_{BC}) = c'(Q_{BH}+Q_{AB}+Q_{BC}) + c'(Q_{CH}+Q_{AC}+Q_{BC}) \tag{7}$$

Equations (2)-(7) have a straightforward interpretation. Marginal revenue in city-pair markets such as AH that include the hub is set equal to marginal cost on the relevant leg (equations (2)-(4)). In non-hub city-pair markets (e.g., AB), marginal revenue is set equal to the sum of marginal costs for the two legs of the trip (equations (5)-(7)).

To facilitate the analysis of competition, we assume linear demand and marginal cost functions, as follows:[16],[17]

A.1.　　　$R'(Q) = \alpha - Q$, $\alpha > 0$,

A.2.　　　$c'(Q) = \delta - \theta Q$, $\delta > 0$, $\theta > 0$.

Under these assumptions, we can state:

Proposition 1:

i) Given A.1. and A.2., the solution to the monopolist's problem is as follows:

$$Q_{AH} = \frac{\alpha - \delta + \theta(Q_{AB} + Q_{AC})}{1 - \theta} \tag{8}$$

$$Q_{BH} = \frac{\alpha - \delta + \theta(Q_{AB} + Q_{BC})}{1 - \theta} \tag{9}$$

$$Q_{CH} = \frac{\alpha - \delta + \theta(Q_{AC} + Q_{BC})}{1 - \theta} \qquad (10)$$

$$Q_{AB} = Q_{AC} = Q_{BC} = \frac{2\delta - \alpha(1 + \theta)}{5\theta - 1} \qquad (11)$$

ii) The second order conditions for the monopolist's problem are satisfied when $\theta < 1/5$;

iii) Positive quantities and marginal revenues require $2\delta/(1+\theta) < \alpha < \delta/3\theta$.

The derivation of (i), while cumbersome, is straightforward and is not provided here. The proof of (ii) is provided in the Appendix. With $\theta < 1/5$ by the second order conditions, (8)-(11) imply that $2\delta/(1+\theta) < \alpha$ must hold for equilibrium quantities to be positive.[18] Furthermore, from (8)-(11), positive marginal revenues require $\alpha < \delta/3\theta$. Thus, $2\delta/(1+\theta) < \alpha < \delta/3\theta$ must hold for both quantities and marginal revenues to be positive, establishing (iii).

The Proposition also has implications for the prices paid by local and pass-through passengers. In particular:

Corollary 1:

The price of a trip between any two nonhub cities is less than the combined prices of the individual hub legs.

It is straightforward to see that (8)-(11) satisfy this arbitrage requirement. In particular, the sum of ticket prices for any two hub legs equals $\alpha + MC$, where MC is marginal cost on each hub leg evaluated at the optimum. The ticket price between any two nonhub cities is $\alpha/2 + MC$, a

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smaller quantity.

If this price relationship did not hold, pass-through passengers could purchase individual leg tickets with a lower combined cost. The result is that passengers that fly to or from the hub pay a higher price per mile than those flying between non-hub cities. Observe that this result does not require different degrees of monopoly power among the different routes.[19]

In the following sections we explore the welfare and distributional implications of the introduction of different types of competition in the monopolist's network.

III. Interhub Competition.

Consider now the case where a competing airline starts serving cities A and B through a different hub (call it K). The entrant will compete with the monopolist in the AB market, but will not provide any service to H or to C. Assume, just for symmetry, that the entrant also serves a city D (see Figure 2). Furthermore, assume that there is no demand for travel for the city pairs HK, CK, HD, CD. Thus, neither airline connects these cities and there are also no joint fare arrangements. While this assumption is artificial, it allows a straightforward comparison of equilibria under monopoly and interhub competition.[20] Assume also that the demand function in A.1. represents the demand for travel in markets AK, BK, DK, AD, and BD, and that the entrant shares the same cost function as the incumbent monopolist. The model, then, is perfectly symmetric. The two firms overlap in an indirect route, AB, but otherwise they serve disjoint regions.

Following entry, the two firms play a Cournot-Nash game in the AB market

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while setting monopoly prices on their respective monopoly routes.[21] Given the symmetry of the model, we concentrate on the symmetric Cournot equilibrium. Let firm 1 be the incumbent, and firm 2 be the entrant. The maximization problem for firm 1 is given by (1) where revenue from city pair AB is now given by $R = Q^1_{AB}[\alpha - (Q^1_{AB} + Q^2_{AB})/2]$.

We can then state:

Proposition 2:

i) Under assumptions A.1. and A.2., the interhub-competition solution for firm 1 (with a symmetric solution for firm 2) is given by (8)-(10) together with:

$$Q^1_{AB} = [2\delta - \alpha(1 + \theta)]\frac{4\theta/3 - 2/3}{8\theta^2 - 19\theta/3 + 1} \qquad (12)$$

$$Q^1_{AC} = Q^1_{BC} = [2\delta - \alpha(1 + \theta)]\frac{5\theta/3 - 1}{8\theta^2 - 19\theta/3 + 1} \qquad (13)$$

ii) The second order conditions for firm 1's problem are satisfied for $\theta < 1/5$;

iii) Positive quantities require $2\delta/(1+\theta) < \alpha$.

iv) The condition for positive marginal revenues under the monopoly solution ($\alpha < \delta/3\theta$) also yields positive marginal revenues under interhub competition.

The derivation of (i), while cumbersome, is straightforward and is not provided here. To prove (ii), observe that the Hessian matrix of (1) is unaffected by the change in the definition of marginal revenue, so that the

second order condition in the monopoly case ($\theta < 1/5$) still applies here. To prove (iii), observe that the denominators in (12) and (13) are positive for $0 < \theta < 1/5$, while the numerators are both negative in this range. Therefore positive quantities again require $2\delta/(1+\theta) < \alpha$. The proof of (iv) is deferred until later.

From Proposition 2, several results can be derived concerning the effect of interhub competition on output and prices in the hub-and-spoke network. We start by stating that Corollary 1 still holds:

Corollary 1a:

   The price of a trip between any two nonhub cities is less than the

   combined prices of the individual hub legs.

The proof of the Corollary follows that of Corollary 1.[22]

Let us analyze now the effect of interhub competition on the AB market. Comparing (11) with (12) we obtain

$$Q^m_{AB} > (<) \; Q^1_{AB} \Leftrightarrow \frac{1}{5\theta - 1} < (>) \frac{4\theta/3 - 2/3}{8\theta^2 - 19\theta/3 + 1}, \qquad (14)$$

where Q^m_{AB} represents the monopoly solution given in (11), and Q^1_{AB} the solution for firm 1. Rearranging, (14) reduces to $(1 - 4\theta)(1 - \theta) < (>) \; 0$. Since $\theta < 1/5$, we obtain $Q^m_{AB} < Q^1_{AB}$. Thus, we can state:

Corollary 2:

   AB traffic through hub H is lower under interhub competition than under

   monopoly.

Since hub-and-spoke airlines are multiproduct firms with strong cost complementarities, the reduction in traffic in the AB market has widespread effects. Lower AB traffic leads to an increase in marginal cost on the AH and BH legs. This in turn raises the marginal cost of a passenger in the AH, BH, AC, and BC markets,[23] leading to price increases and lower traffic levels in these markets. Since lower AC and BC traffic reduces traffic on the CH leg, marginal cost also rises on that leg, which leads to higher prices and lower traffic in the CH market. Thus, interhub competition imposes a negative externality on passengers not directly affected by it.[24] We can state:

Corollary 3:

Under interhub competition, traffic in the following city-pair markets is lower and prices are higher than under monopoly: AH, BH, CH, AC, and BC.

To prove the Corollary, compare AC and BC traffic under both regimes. The appropriate inequality for the comparison is (14) with the right hand side numerator replaced by $5\theta/3-1$ (compare (11) and (13)). Rearranging this inequality shows that Q^m_{AC}, $Q^m_{BC} > (<) Q^1_{AC}$, Q^1_{BC} as $1 - \theta > (<) 0$. With θ below 1, it follows that Q^m_{AC}, $Q^m_{BC} > Q^1_{AC}$, Q^1_{BC}, indicating that traffic level in city-pair markets AC and BC are lower under interhub competition than under monopoly. A similar conclusion can be derived for markets AH, BH, and CH, establishing the Corollary.[25]

Corollary 3 shows that passengers in all city-pair markets other than AB

are better off under monopoly. Traffic levels are higher and prices are lower in these markets under the monopoly solution. Whether passengers in the AB market are better off depends on the effect of interhub competition on the price of AB trips. In general it is reasonable to expect competition to reduce prices. Here, however, because of the increasing returns to scale and cost complementarities with the other services, competition may actually increase prices in the contested city-pair market. Intuition suggests that for this to be the case, economies of scale should be very strong. The following Corollary establishes this result.

Corollary 4:

Interhub competition raises traffic and lowers ticket prices in the AB market when $0 < \theta < .152$. Traffic falls and prices rise when $.152 < \theta < 1/5$.

To prove the Corollary, observe that under interhub competition, total traffic volume is given by $2Q^1_{AB}$. From (14) we obtain that $Q^m_{AB} > (<) 2Q^1_{AB}$ as $16\theta^2 - 9\theta + 1 > (<) 0$. Solving for the roots of this equations yields Corollary 4.

The Corollary shows that when returns to scale are not too strong ($\theta < .152$), interhub competition raises total AB traffic and lowers prices. However, when returns to scale are more substantial ($\theta > .152$), competition lowers total traffic and leads to higher AB prices. This result follows because the reduction in firm 1's AB output is larger the stronger are economies of scale. With θ at the upper end of the $(0,1/5)$ interval, the effect is strong enough to depress total traffic.

Observe that Corollaries 2, 3 and 4 do not depend on the value of the demand intercept α. Thus, all these results will also hold if α were to differ across city-pairs (the demand slopes, however, should remain the same).

Consider now the effects of combining firms 1 and 2 through a merger. The combined firm would still provide service to D from K, as well as providing AK and BK service. Thus, the combined firm will now face no competition in the AB market, and will consequently increase the AB price, independently of the extent of economies of scale. The reduction in AB passengers (through both hubs H and K) will imply that the combined firm's marginal costs on the AH, AK, BH and BK legs will now increase. This increase in costs will lead to a reduction in traffic in the rest of the dual hub-and-spoke network. Thus, we can state:

Corollary 5:

A merger of the two separated hub-and-spoke networks will imply a reduction in overall traffic, and an increase in prices in all city-pair markets.

The proof of this result follows the proofs of Corollaries 2 and 3.

The main reason for Corollary 5 is that there are no cost complementarities between the merging networks. If, however, the two hub-and-spoke networks were linked, so that there was demand for travel in markets CK, CD, HK and HD, then the merger would provide efficiency gains by increasing rather than decreasing aircraft utilization in those city-pairs. These efficiency gains, however, are the same as those to be analyzed in the

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next two cases.

IV. Direct and Leg Competition

Most airline mergers that have raised antitrust concerns were not of the type just discussed. Usually, these mergers implied a substantial increase in the extent of concentration at selected airports and on several nonstop routes. For example in the TWA-Ozark case, the merger substantially increased the concentration of the St. Louis airport, with the combined entity (TWA) accounting for 85% of total departures. In the Northwest-Republic case, the merging partners controlled 79% of total departures out of Minneapolis-St. Paul.[26] In both mergers there were also several nonstop routes out of the hub which showed a substantial increase in the extent of concentration, with the merger usually removing one of the two airlines that served those routes. This is shown in Table 1 for the TWA-Ozark case.

Another type of merger that may also raise antitrust concerns involves a major hub-and-spoke airline and another carrier providing direct service between some of that airline's destination points. The US Air-Piedmont merger seems to fit this category. On the one hand, the airlines had no common hubs. On the other hand, the airlines served a number of common non-hub city-pair markets.[27]

To analyse these two cases, we consider two simple competition models. In one, we analyze the effect on the hub-and-spoke network of competition by a small airline that provides direct service between two of the monopolist's nonhub cities. We call this the "direct-competition" case. The second case is when another small airline provides competition on a single route out of H. We call this the "leg-competition" case.

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IV.a Direct Competition.

Consider first the case where a competing airline (airline 2) provides direct service in the AB market (see Figure 3). This case resembles to some extent the interhub competition case. However, while competition was symmetric under interhub competition, with the firms sharing the AB market equally, that is not the case here. Since firm 2 only serves the AB market, its marginal cost on the AB route depends exclusively on the number of direct AB passengers. On the other hand, firm 1's marginal cost in the AB market depends on the traffic levels throughout its network.

The maximization problem for firm 1 again is given by (1) with $R(Q_{AB})$ replaced by $Q^1_{AB}(\alpha - (Q^1_{AB} + Q^2_{AB})/2)$. Because of the lack of symmetry, however, Q^2_{AB} now has to be solved for.[28] The competing airline's first order condition is now given by[29]

$$\alpha - Q^2_{AB} - Q^1_{AB}/2 = \delta - \theta Q^2_{AB}, \tag{15}$$

which must be added to (2)-(7) to solve for the equilibrium under direct competition. The solution to the augmented system, however, does not have as simple a closed form as that of the interhub-competition case. Furthermore, the comparison of direct competition and monopoly now involves the intercept terms α and δ, making the comparison quite complicated. We thus analyze the direct-competition case through numerical simulations.

Let us start by considering the inequality that guarantees proper solutions for both the monopoly and direct-competition cases (proper solutions are those that satisfy positive output and marginal revenues).

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The first two columns of Table 2 show that the relevant inequality (derived from many separate conditions) is always more restrictive than the one that guarantees proper solutions in both the monopoly and interhub-competition models (recall that proper solutions for both these cases require $2\delta/(1+\theta) < \alpha < \delta/3\theta$.) Note that the inequalities become narrower as θ increases and that proper solutions for both the monopoly and direct competition cases do not exist when θ is greater than .12.[30]

Concentrating exclusively on proper solutions, the comparison between direct competition and monopoly becomes manageable. First, for all proper values of the parameters, total AB traffic under direct competition exceeds AB traffic under monopoly. Thus, AB passengers benefit from direct competition.[31] Column 3 of Table 2 shows, however, that this is not always the case for the remaining passengers in the hub-and-spoke network. First, for relatively large values of θ (i.e., $\theta \geq .04$) traffic volumes in markets other than AB are lower under direct competition than under monopoly.[32] On the other hand, when economies of scale are weak ($\theta < .04$), whether traffic in the hub-and-spoke network falls or increases depends on the relative magnitudes of the demand and marginal cost intercepts. In particular, if the demand intercept, α, is large (small) in relation to the marginal cost intercept, δ, then direct competition increases (decreases) all other network traffic.[33]

The intuition for this result is as follows. Recall, first, that firm 2 has higher marginal costs than firm 1. Thus, the larger the demand intercept, the larger is firm 1's share of total AB traffic. Since total AB traffic rises with direct competition, and since firm 1's share is higher the higher is α, its traffic level is more likely to rise when α is high

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(this outcome also requires a small θ given that the increase in total traffic is lower the stronger are increasing returns). Thus, we can state:[34]

Proposition 3:

  i) ˙ Proper solutions for both monopoly and direct competition cases do not exist when $\theta > .12$;

  ii) Under direct competition, total traffic in the AB market is higher and prices are lower than under monopoly;

  iii) If $\theta \geq .04$, traffic throughout the hub-and-spoke system is lower, and prices in city-pair markets other than AB are higher, under direct competition than under monopoly.

  iv) If $\theta < .04$, traffic throughout the hub-and-spoke system is higher (lower) under direct competition than under monopoly if the demand intercept α is relatively large (small) in relation to the marginal cost intercept δ, in a way specified in Table 2, Column 3.

Direct competition therefore harms all passengers in the hub-and-spoke network outside the AB market when economies of scale are strong, or when economies of scale are weak and demand is relatively low. Under these conditions, a merger of the competing firms would depress traffic and increase prices in the AB market, but increase traffic and depress prices in all other city-pair markets. Such a merger will be detrimental to AB passengers but beneficial for all other passengers.

A comparison of consumer welfare before and after such a merger requires aggregating gains and losses across city-pair markets. Setting δ equal to

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one,[35] calculations show that total consumer surplus across all markets is higher under direct competition than under monopoly when θ = .01, .02, .03, .04, or .06. When θ = .08, .10, or .12, however, direct competition reduces consumer surplus. In the latter cases, the gains in the AB market are not sufficient to offset losses elsewhere.

Whether total surplus is higher under direct competition or monopoly depends also on firms' profits. Total surplus is higher under direct competition than under monopoly when θ = .01, .02, .03, .04, or .06. When θ = .08, total surplus is higher (lower) under direct competition when $\alpha < (>)$ 2.92. When θ = .10 or .12, total surplus is lower under direct competition regardless of the value of α. These results are illustrated in Figure 5. Figure 5 shows the regions in (α,θ) space where the regimes are respectively superior (θ values below .04 and above .12 are not shown in the figure). The upper and lower curves give the range of proper solutions, and the curve in between separates the regions.

Regardless of whether consumer or total welfare is the concern, the above results show that direct competition is harmful when increasing returns are strong and beneficial when increasing returns are weak. The reason of course, is that traffic diversion to the competing firm raises costs for the hub-and-spoke airline most in the case of strong increasing returns. Given these results, we can state:

Corollary 6:

A merger of a hub-and-spoke airline and a direct competitor in one of its non-hub markets will increase (decrease) social welfare if returns to scale are relatively strong (weak).

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IV.b. Leg Competition.

Consider now the case of leg competition, where a small airline provides service to and from the hub H to selected cities in firm 1's network. In the case to be analyzed below, we assume that the airline provides service just to a single city, say A (see Figure 4). This case is intended to resemble the situation in the TWA-Ozark merger case, where Ozark operated a number of routes out of St. Louis (TWA's main hub) but played a smaller role than TWA as a hub carrier.[36]

In this case, airline 2 serves passengers in the AH market but carries no AB or AC passengers. To see this, observe that from Corollaries 1 and 1a, which are also valid here, the cost of an AC ticket is less than the combined cost of AH and CH tickets. Thus, airline 2 carries no pass-through passengers.

The analysis of leg competition parallels that of direct competition, except that the equilibrium conditions for the leg AH are now changed. The first-order condition for firm 2 is given by

$$\alpha - Q^2_{AH} - Q^1_{AH}/2 - \delta - \theta Q^2_{AH}, \tag{16}$$

which is added to the modified system (2)-(7). As in the direct-competition case, closed-form solutions are complex, and the analysis is conducted via simulation. As before, the existence of proper solutions for both the monopoly and leg-competition cases imposes restrictions on α and δ for a given θ. These restrictions are given in Table 3.

Table 3 also shows that for all feasible parameter combinations, leg

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competition reduces traffic throughout the hub-and-spoke network, including the leg AH, while increasing total AH traffic. Thus, we can state:

Proposition 4:

Under leg competition in AH, all proper solutions have the characteristic that:

i) Total traffic in the AH market is larger and prices are lower than under monopoly;

ii) Traffic levels throughout the hub-and-spoke system are lower than under monopoly.

iii) Prices in all city-pair markets other than AH are higher than under monopoly.

Leg competition thus harms passengers in the hub-and-spoke network other than those in the AH market. While a merger of the competing firms would increase prices in this market, it would increase traffic and reduce prices throughout the rest of the hub-and-spoke system. Such a merger is therefore detrimental to AH passengers but beneficial for all other passengers.

Setting δ again equal to one, calculations show that total consumer surplus is higher under leg competition than under monopoly when $\theta = .02$, .04, .06, .08, .10, or .12. For these θ values, gains in the AH market offset losses elsewhere. When $\theta = .14$, .16, consumer surplus is higher (lower) under leg competition when α is small (large) (the critical α values are 2.00 and 1.78 respectively). When $\theta = .18$, consumer surplus is higher under monopoly regardless of the value of α.

Total surplus shows a similar pattern, with total surplus being higher

under leg competition when θ = .02 or .04, lower under leg competition when θ = .14, .16, or .18, and higher (lower) under leg competition when θ = .06, .08, .10 , or .12 as α is small (large).[37] Figure 6 shows the regions in (α,θ) space where the regimes are respectively superior (θ values below .04 and above .14 are not shown).

As in the case of direct competition, the above results show that leg competition provides higher (lower) total surplus than monopoly when increasing returns are weak (strong). For intermediate values of returns to scale, however, the nature of demand determines whether competition or monopoly maximizes social surplus. In particular, competition (monopoly) is the efficient structure for low (high) demand levels. This pattern also emerges in the direct-competition surplus calculations performed above. The apparent reason is that because of the linearity of marginal costs, low demand reduces the hub airline's ability to exploit increasing returns, making the traffic-diversion effect of competition less serious.

In view of the above results, we can state

Corollary 7:

   A merger of a hub-and-spoke airline and a competitor on one of its hub legs will increase (decrease) social welfare when increasing returns are strong (weak). When returns to scale are of intermediate strength, a merger will increase (decrease) social welfare when demand is relatively high (low).

V. Final Comments.

   The above results show the potential benefits of mergers in airline hub-

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and-spoke systems. The source of the social gains from mergers is the cost-complementarity inherent to hub-and-spoke networks. By increasing traffic and hence aircraft utilization on feeder routes, a merger reduces marginal cost for both local and pass-through passengers. This reduction in marginal costs typically lowers the equilibrium prices outside the contested market, increasing consumer welfare. In general, the probability that such distributional effects of the merger are accompanied by an increase in total social welfare increases with the extent of economies of scale and the size of demand.

This paper suggests that the application of standard antitrust methodologies to network airlines may be erroneous. Most welfare gains from these mergers will occur in markets other than those where increases in market power occur. Thus, exclusive focus on welfare gains and losses in the "antitrust" markets may have the effect of blocking socially efficient mergers. The paper thus suggests an important reconsideration of antitrust policy towards airline mergers.

Finally, this paper has very simple empirical implications concerning necessary conditions for a merger to generate welfare gains. For example, for a merger to generate an increase in social welfare, total hub traffic for the combined airline has to increase and prices for their hub passengers have to decrease following the merger. Also, the combined airline should use larger aircraft following the merger. Similarly, other carriers serving the same hub should show a reduction in their market share and in their average aircraft size. Otherwise, the merger did not generate network efficiencies. While these are necessary and not sufficient conditions for an increase in welfare, they are easy to check. For example, following the

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TWA-Ozark merger, TWA increased the number of direct routes out of St. Louis from 85 in June 1986 to 91 in June 1987 and increased from 72 to 74 the number of cities served with jet aircraft. On the other hand, during the same period, other carriers serving St. Louis reduced the number of their direct routes from 83 to 66, and the number of cities served with jet service from 62 to 60.[38,39] This evidence, then, is consistent with the TWA-Ozark merger having increased the efficiency of the combined airline, which is a necessary, but not sufficient, condition for increasing total welfare.[40]

Proof of Proposition 1. ii):

The second order conditions for the monopolist problem specified in (1) are the following:

$$\theta - 1 < 0 \tag{A1}$$

$$(\theta - 1)^2 > 0 \tag{A2}$$

$$(\theta - 1)^3 < 0 \tag{A3}$$

$$(\theta - 1)^2(1 - 3\theta) > 0 \tag{A4}$$

$$(\theta - 1)^4(3\theta - 1) + 4(\theta - 1)^3\theta^2 + 3\theta^4(\theta - 1) < 0 \tag{A5}$$

$$\theta^4(2\theta - 1)(\theta - 5) + (\theta - 1)^4(1 - 5\theta) +$$

$$2\theta^2(\theta - 1)\{(2\theta - 1)^2 + \theta(\theta - 1)(2 - \theta)\} > 0. \tag{A6}$$

It is easily seen that (A1)-(A5) are satisfied provided that $\theta < 1/3$. Calculations show that in the range where $0 < \theta < 1/3$, (A6) is satisfied for $\theta \in (0,1/5)$, establishing Proposition 1 (ii).

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1.   For important exceptions, see Carlton and Klamer (1983), and Carlton, Landes and Posner (1980).

2.   Network efficiencies could be achieved through airlines coordinating their schedules to avoid competing departure times and to minimize pass-through passengers' waiting time (see Carlton and Klamer (1983)).   While airlines' coordination could increase the efficiency of the network, passengers seem to prefer same-airline to multi-airline connections (Carlton, Landes and Posner (1980)).   Thus, the efficiencies achieved through mergers may not be available through coordination.

3.   Meyer and Oster Jr. (1987, p.80) speculate that the hub-and-spoke network will eventually become obsolete as new aircraft technologies make smaller aircraft competitive in long distance routes.

4.   Spokes are usually non-stop single-destination routes, with one of the end-points being the hub.   Aircraft economies have also reduced the efficiency of tag-end service, i.e., service where there is more than one stop between the hub and the end-point.   For example, according to a Justice Department expert witness, Republic reduced its share of nonhub segments from 39% in January 1985 to 7% in March 1986.   (See In re NWA-REPUBLIC ACQUISITION CASE, Rebuttal Testimony and Exhibits of the Department of Justice, Docket 43754, p: 6.)

5.   Section 408(b)(1)(B) of the Federal Aviation Act, as amended, specifies that mergers among certificated air carriers that tend to reduce competition in any region of the United States should be prohibited, unless the anticompetitive effects are outweighed by their efficiency gains.   See 49 U.S.C. #1378 (b)(1)(B).   Before the passage of the Airline Deregulation Act of 1978, the enforcement responsibility resided with the CAB.   DOT's responsibility for airline mergers statutorily expires in 1989, and will be transferred to the FTC and to the Department of Justice, as is the usual case with regular mergers.

6.   Since January 1, 1985, the Department of Transportation reviewed 22 airline merger cases.   Of these, the DOT did not block any merger.   The merger was eventually approved subject to a modification of the transaction. The Department of Justice, however, took a position against three merger cases (United-Pan Am Pacific Division Transfer, NWA-Republic, and TWA Ozark. Both the DOT and DOJ, however, dissapproved of the terms of the Texas Air-Eastern.   (The merger was eventually consummated with Eastern divesting of several shuttle slots.)   See Mergers/Acquisitions Involving Large Certificated Air Carriers Reviewed by the Department Since January 1, 1985, Department of Transportation memorandum.

7.   The DOJ systematically defines "antitrust airline markets" as non-stop city-pair service.   See, for example, In re NWA-REPUBLIC ACQUISITION CASE, Proposed Findings of Fact of the Department of Justice, Docket 43754, pp: 2-6.   The DOT, however, has systematically used a wider definition of the

"antitrust airline market." The DOT defines the antitrust market as a city-pair, but includes connecting service. See for example, In re NWA-Republic ACQUISITION CASE, Opinion and Order, Department of Transportation, Docket 43754, pp: 8-11; In re USAIR-PIEDMONT ACQUISITION CASE, Final Order, Department of Transportation, Docket 44719, p: 3, and In Re TWA-OZARK ACQUISITION CASE, Opinion and Order, Department of Transportation, Docket 43837, pp:3-6. For an analysis of the concept of antitrust rather than economic markets see Scheffman and Spiller (1987).

8. For example, in the TWA-Ozark merger, the DOJ claimed that the merger would reduce the number of actual providers from two to one in 19 non-stop markets (the usual DOJ definition of antitrust markets, see previous footnote), and from three to two in six other antitrust markets. (See In re TWA-OZARK ACQUISITION CASE, Post Hearing Brief of the Department of Justice, Docket 43837, pp: 43-44.) Similarly, in the Northwest-Republic merger, the DOJ claimed that there were 27 markets where the reduction in the number of actual providers was from two to one, while there were six markets where the reduction of the numbers of firms was from three to two. (See In re NWA-REPUBLIC ACQUISITION CASE, Amended Post-Hearing Brief of the Department of Justice, Docket 43754, pp:30-33). The DOJ assessed, for the latter merger, the annual revenues of these markets as $900 million, and the annual welfare loss from the reduction in competition from $2.7 to $14.7 million (See In re NWA-REPUBLIC ACQUISITION CASE, Comments of the United States Department of Justice, Docket 43754, Appendix I).

9. For example, the Applicants in the NWA-Republic merger argued that "the merger will enhance efficiency by eliminating Republic's wing-tip to wing-tip service." The DOJ responded, however, that, "if it is efficient for Republic to use larger planes ..., the two carriers can negotiate a mutually beneficial equipment swap or sale,..., without creating the competitive harm of this particular merger." (See In re NWA-REPUBLIC ACQUISITION CASE, Post-Hearing reply of the Department of Justice, Docket 43754, p: 14).

10. See In re NWA-REPUBLIC ACQUISITION CASE, Proposed Findings of Fact and Conclusions of Law of the Department of Justice, Docket 43754, p: 27). The DOT, however, has taken a clear opposite view on this respect. See, for example, In re TWA-OZARK ACQUISITION CASE, Opinion and Order, Department of Transportation, Docket 43837, pp: 6-7.

11. See, in particular, Perry and Porter (1985) and Farrell and Shapiro (1988), and references therein.

12. For example, while continuously growing, it took eight quarters for People's Express (from III/81 to II/83 inclusive) to exceed 100 daily departures out of Newark. (See In re TWA-OZARK ACQUISITION CASE, Direct Testimony and Exhibits of the United States Department of Justice, Docket 43837, Table DOJ-D-209.) Similarly, it took American more than one year to establish a hub at Raleigh-Durham with more than 120 daily departures. (See In re US AIR-PIEDMON ACQUISITION CASE, Final Order, Department of Transportation, Docket 44719, p: 13.) Thus, there are nontrivial nonrecoverable expansion costs. See Spiller (1985) for a discussion of this issue.

13. For example, in the TWA-Ozark case, Ozark's gates in St. Louis were in a different terminal than TWA's. Thus, connecting passengers for the combined entity faced a potential increase in their on-land time. This inefficiency was to some extent solved, however, by the introduction of a shuttle service between the two terminals.

14. While connecting service usually involves not more than one extra hour in scheduled travel time, connecting service may involve a non-trivial probability of missing connections or of late arrival. Similarly, connecting service is associated with a higher probability of baggage mishandling. In Reiss and Spiller (1988) direct passengers value direct over connecting service by approximately one hundred 1982 dollars for 900 mile flights. Thus, according to that calculation, passengers seem to value direct service by more than an hour of their time.

15. To avoid excess clutter, we assume further that passengers do not value nonstop service over and above connecting service. See, however, footnote 14.

16. The underlying inverse demand function is given by $D(Q) = \alpha - Q/2$. Note that the choice of measurement units allows the coefficient of Q in the marginal revenue function to be normalized to one.

17. Although the assumption of identical demand functions is restrictive, we relax it below by allowing the intercept α to vary across markets.

18. This inequality guarantees positive quantities in (11). Since the inequality also implies that $\alpha > \delta$ (recall $\theta < 1/5$), positive quantities also emerge in (8)-(10).

19. Spiller (1988) derives a similar result assuming constant marginal costs up to a capacity constraint. There, because of capacity constraints, local passengers under competition pay higher prices per mile than those flying through the hub. Thus, the result that local passengers seem to pay higher prices than those flying through the hub does not imply any differential extent of monopoly power across different routes, and instead seems to depend on the advantages inherent to the hub-and-spoke system.

20. Without this assumption, introduction of a competing hub would alter the number of markets served by the original airline, precluding a proper comparison

21. The Cournot assumption is, in fact, inconsequential. Given the decreasing marginal cost assumption, short run marginal cost pricing is not sustainable. Any other solution concept implying a more cooperative outcome would lead to results qualitatively similar to those derived under the Cournot assumption.

22. Under interhub competition, the price of AH and BH trips together sum to $\alpha + MC$, while the price of an AB trip cost $\alpha/3 + 4MC/3$, with MC representing the marginal cost of the AH and BH legs. The former exceeds the latter when $2\alpha > MC$, which can be shown to hold using the first-order conditions. BH and CH trips together cost $\alpha + (MC+MC^*)/2$, where MC^* is the marginal cost on the CH leg, while the cost of a BC trip is $\alpha/2 +$

$(MC+MC\star)/2$.

23.   Recall that the marginal cost of a passenger in, say, the BC market is given by $c'(Q_{BH}+Q^1_{AB}+Q_{BC}) + c'(Q_{CH}+Q_{AC}+Q_{BC})$.   Thus, since $c''(.)< 0$, a decrease in Q^1_{AB} will increase firm 1's marginal cost in the BC market.

24.   The assumption of increasing returns to scale is crucial for this result.   In particular, if there were decreasing returns to scale, traffic in all city-pair markets would increase with interhub competition.

25.   Given (8)-(10), the reduction in hub-and-spoke traffic in markets AB, AC, and BC implies lower traffic in markets AH, BH, and CH.   The above results can also be used to prove part (iv) of Proposition 2.   In particular, since traffic falls with interhub competition, it follows that marginal costs rise on the hub legs.   This in turn implies that marginal revenues rise in all city-pair markets.

26.   See In re TWA-Ozark Acquisition Case, Direct Testimony and Exhibits of the US Department of Justice, Docket 43837, Table DOJ-D-105, and In re NWA-Republic Acquisition Case, Direct Testimony and Exhibits of the US Department of Justice, Docket 43754, Table DOJ-D-105.

27.   See, In re US Air-Piedmont Acquisition Case, Docket 44719, US Department of Transportation, Office of the Secretary, Final Order, October 30, 1987, pp:10-12.   In few instances, like in the city-pair Dayton-Pittsburgh, both end-points represented a hub for each airline.   In this case, however, both airlines competed for, say, Pittsburgh-Los Angeles or Dayton-Miami passengers.

28.   Previously, Q^1_{AB} was equal to Q^2_{AB} by the symmetry of the problem.

29.   Note that this equation embodies the assumption that airline 2 provides nonstop AB service, since its marginal cost is evaluated at the traffic level in that market alone.   Also, note that we have assumed that passengers are indifferent between nonstop or connecting service.   If nonstop service was valued over connecting service, then the competitor could charge a slightly higher price than the hub airline.

30.   Recall that in both the monopoly and interhub competition cases proper solutions existed for $\theta<.2$.

31.   Recall that in the interhub-competition case, AB passengers were worse off under competition only for very large values of θ ($\theta>.152$).   These very large economies of scale, however, do not yield proper solutions under direct competition.

32.   This outcome is referred to as "X" in Table 2, with the last column showing that X occurs in the range $.04 \leq \theta \leq .12$.   Outcome X is formally described at the bottom of the Table, with the "1" superscript denoting the direct competition case.

33.   Table 2 shows that outcome "Y", where traffic levels rise on all routes, is obtained when α lies in the upper ranges of the admissible intervals.

34.   It is easily seen that the second-order conditions for the hub airline again require $\theta < 1/5$, with the Hessian matrix remaining the same. Also, it is easy to check that profits are positive for both the entrant and the hub airline in all proper solutions. These observations also apply to the leg-competition case discussed below.

35.   For a given θ, surplus values depend on the levels of both α and δ. To simplify the simulations, we assume $\delta - 1$, while letting α vary.

36.   For example, from the 19 nonstop city-pairs where the TWA-Ozark merger implied a combined 100% market share, the percent of local traffic was 28%. However, in those routes where Ozark was the dominant carrier, the percent of local traffic was 34% against only 25% for TWA dominated routes. Thus, Ozark provided a lower degree of hub service than TWA. See Table 1.

37.   The critical α values in the latter cases are 5.50, 2.48, 2.04, and 1.86 respectively.

38.   See U.S. General Accounting Office, <u>Airline Mergers: Changes in Fares and Service for St. Louis Passengers Since the Merger of TWA and Ozark</u>, (1988), Tables 2.1 and 2.2.

39.   The evidence on prices is mixed. Prices out of St. Louis went up following the merger by more than the average for the economy as a whole. However, the highest average price increase occurred in those routes where both TWA and Ozark competed with other carriers, rather than in the routes where TWA and Ozark were the only two providers. Unfortunately the report does not provide evidence on pricing for TWA's pass-through passengers.

40.   There is an alternative explanation for some of these results. Assume that when customers make their reservations, the probability of contacting a given airline increases with its share of total departures. Thus, by simply changing the name of Ozark to TWA and maintaining the same number of combined departures, TWA could get a higher share of traffic. However, this does not fully explain the increase in the number of cities served by the combined airline.

TABLE 1

CITY-PAIRS DOMINATED BY TWA AND OZARK
MEASURED BY NONSTOP DEPARTURES[1]

CITY PAIR	TWA MARKET SHARE[2]	OZARK MARKET SHARE	PERCENT LOCAL PASSENG.	DAILY DIRECT DEPARTS.	% LOCAL IN OZARK DOMINATED ROUTES[3]	% LOCAL IN TWA DOMINATED ROUTES
BALTIMORE	66	34	32	7		32
CLEVELAND	64	36	33.7	6.5		33.7
DES MOINES	45	55	15.7	6.5	15.7	
FT. LAUDERDALE	32	68	49.2	3	49.2	
INDIANAPOLIS	71	29	16.1	10		16.1
LAS VEGAS	85	15	42.8	6		42.8
LOUISVILLE	66	34	15.9	7		15.9
MILWAUKEE	0	100	34.1	8	34.1	
NASHVILLE	62	38	20.4	7		20.4
OKLAHOMA CITY	90	10	22.1	7		22.1
OMAHA	62	38	23.7	7		23.7
ORLANDO	37	63	42	5.5	42	
PEORIA	57	43	7	5.5		7
PHILADELPHIA	89	11	29.3	9		29.3
SAN ANTONIO	50	50	27.8	5	27.8	
SAN DIEGO	73	27	33	5.5		33
TAMPA	44	56	36.8	7	36.8	
TULSA	67	33	16	7		16
WASHINGTON	77	23	33.6	18.5		33.6
AVERAGE	59.84	40.16	27.96	7.26	34.27	25.04
WEIG. AVERAGE[4]	62.45	37.55				

Notes:

1.   Source: In re TWA-Ozark Acquisition Case, Direct Testimony and Exhibits of the US Department of Justice, Docket 43837, Tables DOJ-D-101, DOJ-D-201, DOJ-D-208.

2.   Market shares measured in direct departures.

3.   Routes with Ozark having at least 50% market share.

4.   Weighted by the total number of direct departures in each city.

TABLE 2

COMPARISON OF MONOPOLY AND DIRECT-COMPETITION EQUILIBRIA

	CONDITION FOR PROPER SOLUTIONS IN		OUTCOME WITH DIRECT COMPETITION
	Monopoly and Interhub Competition Cases	Monopoly and Direct Competition Cases	
$\theta=.01$	$1.98\delta < \alpha < 33.33\delta$	$2.99\delta < \alpha < 30.94\delta$	X if $\alpha < 6.52\delta$; Y if $\alpha > 6.52\delta$
$\theta=.02$	$1.96\delta < \alpha < 16.67\delta$	$2.97\delta < \alpha < 15.93\delta$	X if $\alpha < 7.20\delta$; Y if $\alpha > 7.20\delta$
$\theta=.03$	$1.94\delta < \alpha < 11.11\delta$	$2.96\delta < \alpha < 10.91\delta$	X if $\alpha < 8.15\delta$; Y if $\alpha > 8.15\delta$
$\theta=.04$	$1.92\delta < \alpha < 8.33\delta$	$2.94\delta < \alpha < 8.33\delta$	X
$\theta=.06$	$1.89\delta < \alpha < 5.56\delta$	$2.88\delta < \alpha < 5.56\delta$	X
$\theta=.08$	$1.85\delta < \alpha < 4.17\delta$	$2.82\delta < \alpha < 4.17\delta$	X
$\theta=.10$	$1.82\delta < \alpha < 3.33\delta$	$2.74\delta < \alpha < 3.33\delta$	X
$\theta=.12$	$1.78\delta < \alpha < 2.78\delta$	$2.64\delta < \alpha < 2.78\delta$	X
$\theta=.14$	$1.75\delta < \alpha < 2.38\delta$	none	none
$\theta=.16$	$1.72\delta < \alpha < 2.08\delta$	none	none
$\theta=.18$	$1.69\delta < \alpha < 1.85\delta$	none	none

Outcome X: $Q^1_{ij} < Q^m_{ij}$, ij — AH, BH, CH, AB, AC, BC

$Q^1_{AB} + Q^2_{AB} > Q^m_{AB}$

Outcome Y: $Q^1_{ij} > Q^m_{ij}$, ij — AH, BH, CH, AB, AC, BC

$Q^1_{AB} + Q^2_{AB} > Q^m_{AB}$

TABLE 3

COMPARISON OF MONOPOLY AND LEG-COMPETITION EQUILIBRIA

	Proper solutions require:	Outcome
$\theta = .02$	$1.97\delta < \alpha < 16.67\delta$	X
$\theta = .04$	$1.93\delta < \alpha < 8.33\delta$	X
$\theta = .06$	$1.90\delta < \alpha < 5.56\delta$	X
$\theta = .08$	$1.87\delta < \alpha < 4.17\delta$	X
$\theta = .10$	$1.84\delta < \alpha < 3.33\delta$	X
$\theta = .12$	$1.81\delta < \alpha < 2.78\delta$	X
$\theta = .14$	$1.78\delta < \alpha < 2.38\delta$	X
$\theta = .16$	$1.75\delta < \alpha < 2.08\delta$	X
$\theta = .18$	$1.72\delta < \alpha < 1.82\delta$	X

Outcome X: $Q^1_{ij} < Q^m_{ij}$, $ij = $ AH, BH, CH, AB, AC, BC

$Q^1_{AH} + Q^2_{AH} > Q^m_{AH}$

FIGURE 1
A SIMPLE HUB-AND-SPOKE NETWORK
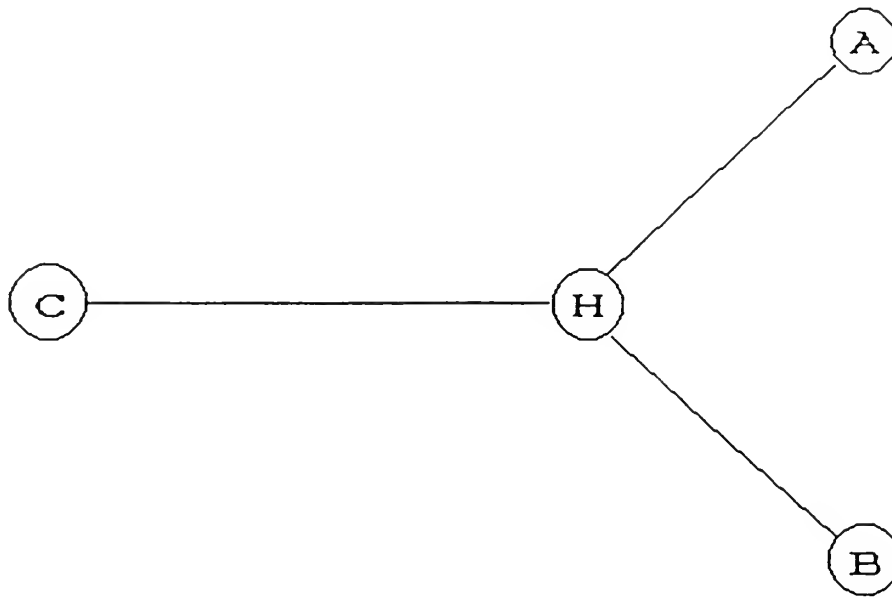
FIGURE 2
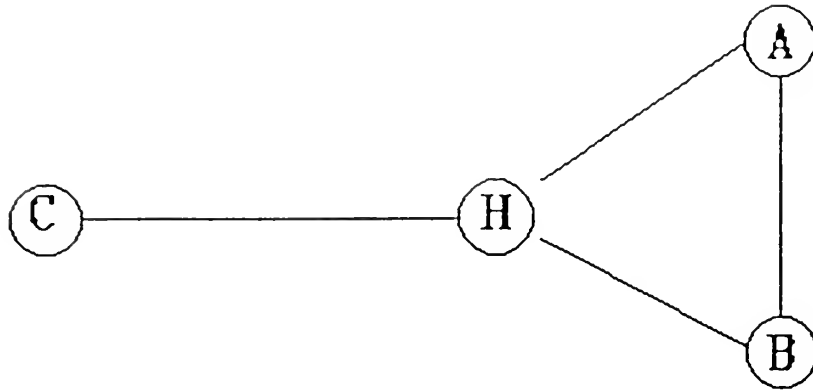## INTER-HUB COMPETITION
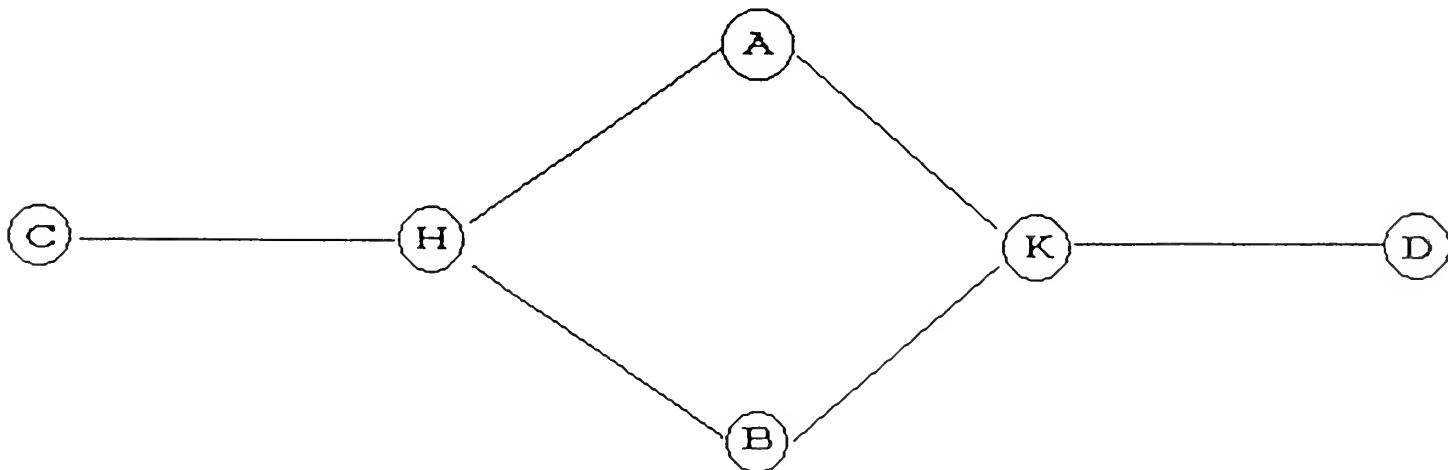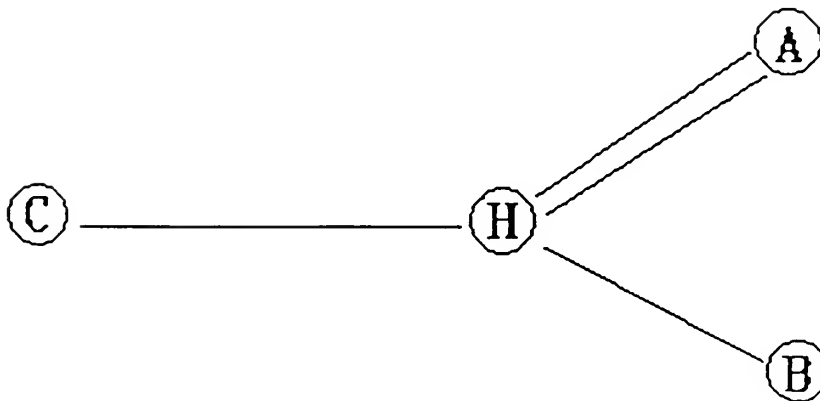
FIGURE 3
DIRECT COMPETITION IN AB

FIGURE 4
LEG COMPETITION IN AH
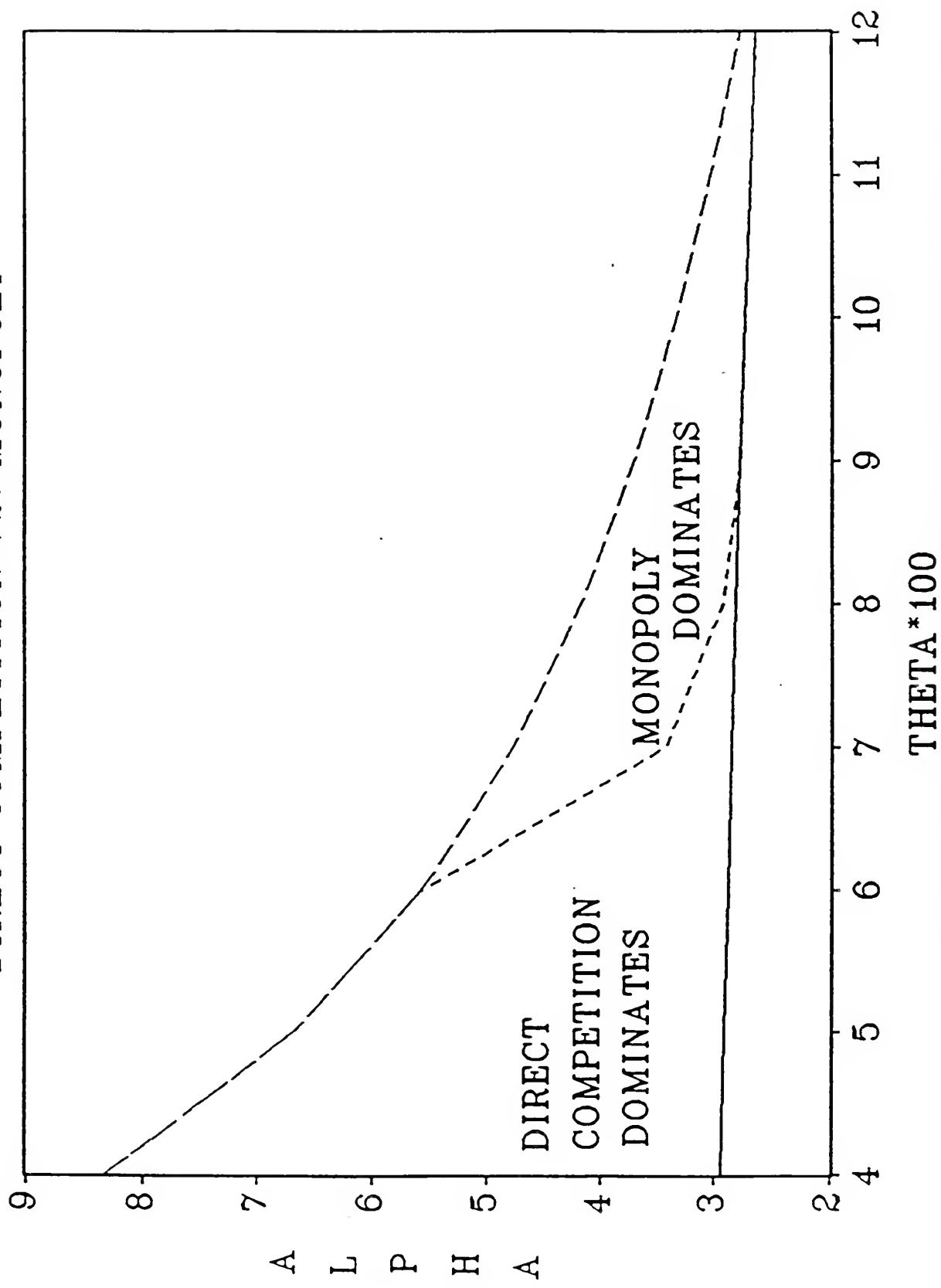
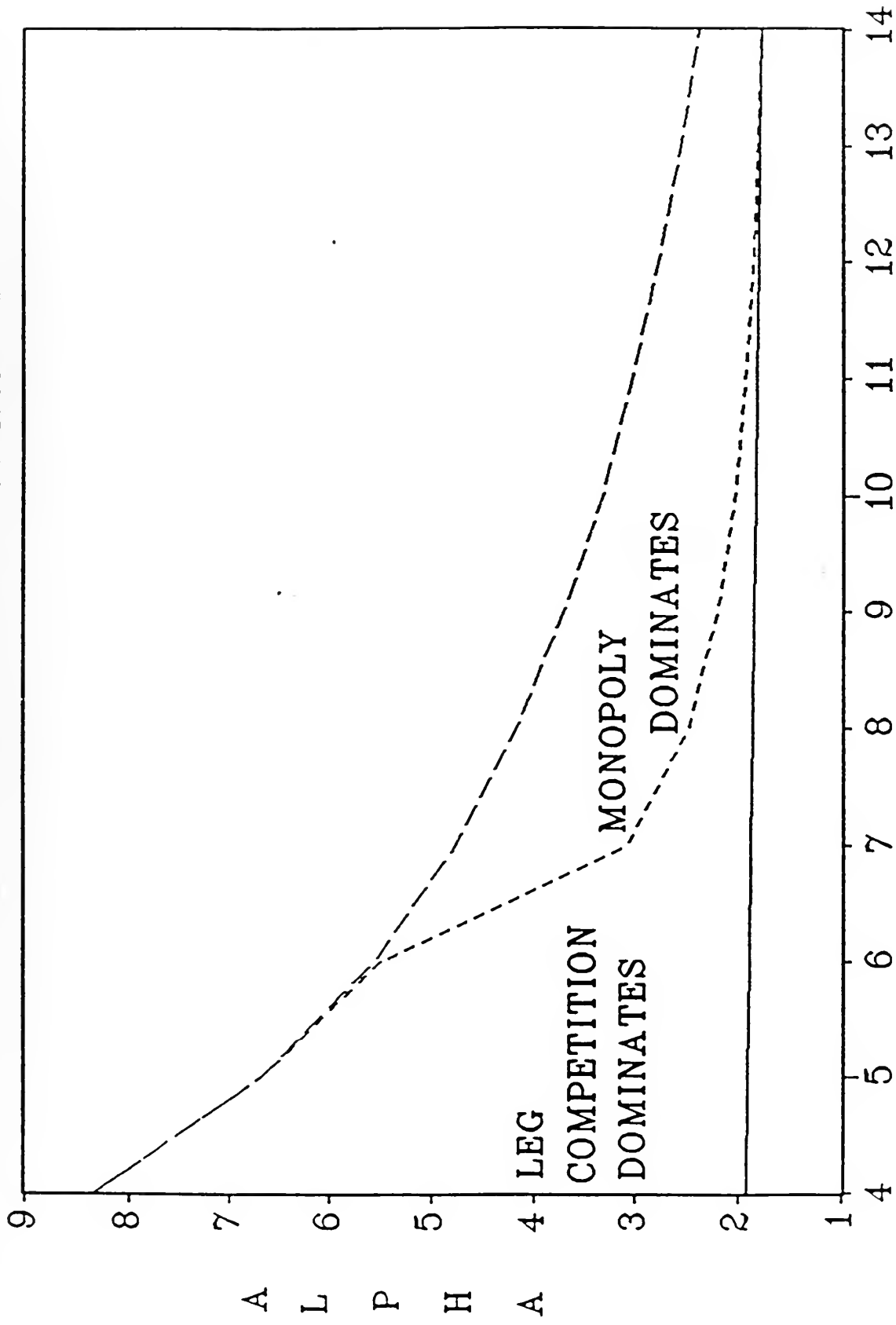TOTAL SURPLUS COMPARISON

DIRECT COMPETITION vs. MONOPOLY

MONOPOLY
DOMINATES

DIRECT
COMPETITION
DOMINATES

THETA*100

FIGURE 5

TOTAL SURPLUS COMPARISON

LEG COMPETITION vs MONOPOLY

THETA*100

FIGURE 6